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PARTIAL CUTTING IN OLD-GROWTH SPRUCE-FIR

by Robert R. Alexander

Abstract

Guidelines are provided to aid the forest manager in developing partial cutting practices needed to convert old-growth spruce-fir forests into managed stands, while maintaining continuous forest cover in travel influence zones and areas of high recreational values or outstanding scenic beauty. These guidelines consider stand conditions, windfall risk, and insect susceptibility. The cutting practices can be used in combination with small cleared openings to create the kinds of stands desirable for increased water yields, to improve wildlife habitat, and to integrate timber production with other uses. They can also be used on areas that are difficult to regenerate where timber production is the primary objective.

Oxford: 221.42:421.1. **Keywords:** Partial cutting, windthrow, multiple use (forest resources), *Picea engelmannii, Abies lasiocarpa.*

About the cover:

Group selection cutting in spruce-fir on the Fraser Experimental Forest. About half the volume was removed from a third of the area in group cuttings about one tree height in diameter. Subsequent blowdown losses were light.

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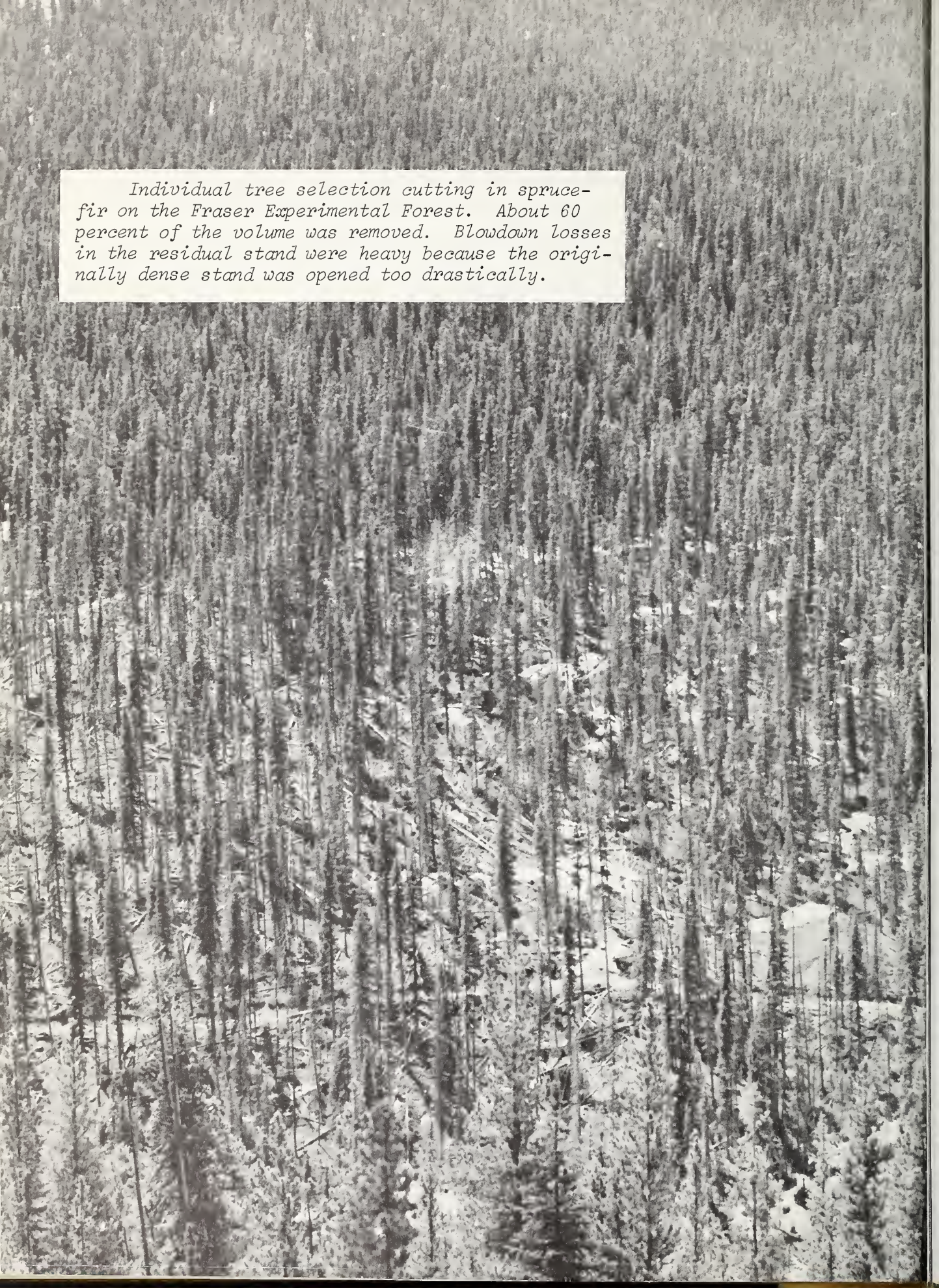
Author's Preface

This publication supersedes Research Paper RM-76, "Initial partial cutting in old-growth spruce-fir," in which I provided guidelines for initial cutting only. The revisions and improvements to the original are in response to requests by users for information on how stands should be handled after the initial harvest, and for practices needed to obtain natural regeneration after partial cutting. Other changes are the result of greater insight obtained by applying those original guidelines in field studies.

For convenient field use, the stand descriptions and cutting guides in this Research Paper were published separately in a smaller format as USDA Forest Service Research Paper RM-76A, "Initial Partial Cutting in Old-Growth Spruce-Fir — Field Guide to Stand Descriptions and Cutting Practices." Although it contains suggested practices only for initial entry, information in this original Field Guide is still appropriate, and can be used in conjunction with the newer guidelines published here. Copies of RM-76A are available from the Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado 80521.



Individual tree selection cutting in spruce-fir on the Fraser Experimental Forest. About 60 percent of the volume was removed. Blowdown losses in the residual stand were heavy because the originally dense stand was opened too drastically.

Partial Cutting in Old-Growth Spruce-Fir

Robert R. Alexander

INTRODUCTION

The Engelmann spruce (Picea engelmannii Parry) — subalpine fir (Abies lasiocarpa (Hook.) Nutt.) type is the largest and most productive timber resource in the central Rocky Mountains (Choate 1963, Miller and Choate 1964). A large proportion of the spruce-fir type is in overmature sawtimber stands that offer little opportunity for management, however, because of their advanced age, relatively slow growth, and susceptibility to wind and insects. Also, many of these natural stands developed after fires or other disturbances and do not have an all-aged structure. Therefore, forest managers concerned with timber production have most often elected to convert this old-growth to managed even-aged stands.[2] Harvesting and regeneration practices developed in the central Rocky Mountains have therefore been directed toward clearcutting.

In addition to being the most productive timber type in the central Rocky Mountains, however, spruce-fir forests are also the highest water yielding, and are valuable wildlife, recreation, and scenic areas. Because of increasing demands on forest lands from a rapidly expanding population and the limited resource available, management must consider all key land uses. The visual and environmental impacts of clearcutting for timber production are not always compatible with the objectives of other key uses. Furthermore, many areas have been difficult to regenerate after clearcutting.

The next section describes the form, structure, and arrangement of stands that are desirable for increased water yields, improvement of wildlife habitat, preservation of the forest landscape, and maintenance of scenic values. Silvicultural practices are later developed that can be used alone or in combination with small cleared openings to maintain forest cover while gradually replacing the old stand with a healthy, vigorous new one.

MULTIPLE-USE SILVICULTURE

Water

Water-yield studies have indicated that the increase in snow depth in openings cut in spruce-fir forests is not additional snow but a change in deposition pattern (Hoover and Leaf 1967). Snow blows off adjacent standing trees and settles in the openings. The increased snow in the openings means that more water is available for streamflow. Research and experience suggest that a round or patch-shaped opening, about five to eight times (in diameter) the height of surrounding trees, is the most effective for trapping snow (Hoover 1969). In larger openings, wind dips to the ground and scours and blows snow out of the opening.

About one-third of the forest area should be in openings, which would be periodically recut when tree height reaches one-half the height of surrounding trees. The remaining two-thirds of the area would be retained as continuous high forest; trees would be periodically harvested on an individual tree basis. Ultimately the reserve stand would approach an all-aged structure with the overstory canopy remaining at about the same height, although the original overstory could not be maintained indefinitely.

An alternative would be to make a light cut distributed over the entire watershed, removing about 20 to 30 percent of the basal area on an individual-tree basis or in small groups. The objective would be to open up the stand enough to develop windfirmness, and salvage low-vigor and poor-risk trees. Openings five to eight times tree height could then be cut on about one-third of the area. The remaining two-thirds of the area would be retained as

[2] *Considerable literature is available on the silvical characteristics of spruce, and spruce regeneration requirements and practices for timber production, but that work will not be reviewed here. Good discussions are presented by Alexander (1958), Roe et al. (1970), and in a manuscript Alexander is preparing on "Silviculture of subalpine forests in the central and southern Rocky Mountains: The state of the art," to be published in the Research Paper RM- series.*

permanent high forest, with trees periodically removed on an individual-tree basis or in small groups.

Another alternative that would integrate water and timber production would be to harvest all the old-growth in a cutting block in a series of cuts spread over a period of 120 to 160 years. Each cutting block would contain at least 300 acres, subdivided into round or patch-shaped units approximately 2 acres in size or four to five times (in diameter) the height of a general canopy level. At periodic intervals, some of these units, distributed over the cutting block, would be harvested and the openings regenerated. The interval between cuttings could vary from as often as every 10 years to as infrequently as every 30 to 40 years. The percentage of units cut at each interval would be determined by Cutting cycle/Rotation age times 100. At the end of one rotation, each cutting block would be composed of groups of trees in several age classes ranging from reproduction to trees ready for harvest. The height of the tallest trees would be somewhat less than the original overstory, but any adverse effect on snow deposition should be minimized by keeping the openings small and widely spaced.

Wildlife

Big game use of spruce-fir forests can be improved by certain timber cutting practices.

Openings of less than 20 acres cut in the canopy of spruce-fir forests in Arizona were heavily used by desert mule deer (Odocoileus hemionus Rafinesque) and American elk (Cervus canadensis (Erxleben) Reynolds), but use decreased considerably in larger openings (Reynolds 1966). Openings created by harvesting were preferred to natural openings because the vegetation that initially comes in on cutovers is more palatable to deer and elk. Reynolds suggested that openings be maintained by cleaning up the logging slash and debris, removing new tree reproduction, and seeding the area to forage species palatable to big game. However, since the more palatable species are likely to be replaced during natural succession on the cutover areas, a more desirable alternative would be to cut new openings periodically while allowing the older cuttings to regenerate. That would provide a constant source of palatable forage and the edge effect desired, while creating an all-aged forest by even-aged groups. The openings created should be widely spaced, with the stand between openings maintained as high forest.

On the Fraser Experimental Forest in Colorado, Rocky Mountain mule deer use in spruce-fir forests was greater and forage more abundant on cleared openings than in the uncut forest (Wallmo 1969). Clearcut openings 3 chains wide were used more than wider or narrower openings. Forage production appears to decline about 10 years after cutting, however, as tree reproduction replaces forage species (Wallmo et al. 1972). While no recommendations were made as to optimum size or arrangement of openings, the Fraser study suggests that they be kept small and interspersed with standing trees that could be periodically harvested on an individual tree basis.

One alternative that would integrate wildlife habitat improvement with timber production would be to cut about one-sixth of a cutting block every 20 years in openings about four to five times tree height. Each Working Circle would be subdivided into a number of cutting blocks (of at least 300 acres) so that not all periodic cuts would be made in a single year on a Working Circle. Such periodic cutting would provide a good combination of numbers and species of palatable forage plants and the edge effect desired, while creating a several-aged forest of even-aged groups.

Wildlife other than big game is also influenced by the way forests are handled. For example, with the curtailment of wildfires, some reduction in stand density by logging is probably necessary to create or maintain drumming grounds for male blue grouse (Dendragapus obscurus Say). Partial cutting that opens up the canopy enough to allow tree regeneration to become established in scattered thickets appears to provide the most desirable habitat. Cutting small, irregularly shaped openings (up to 10 acres) in the canopy may also be beneficial to blue grouse, if thickets of new reproduction become established in the cleared openings (Martinka 1972).

Recreation and Esthetics

Permanent forest cover at least in part is preferred in recreation areas, travel influence zones, and scenic view areas. Since old-growth spruce-fir forests will not maintain themselves in an esthetically pleasing or sound condition indefinitely, some form of partial cutting can help retain forest cover while at the same time replacing the old with a new stand. However, the visual impact of logging operations — haul roads, damage to residual trees, and slash and debris — must be minimized. In situations where there is no harvesting alternative to clearcutting, and the environmental impact of clearcutting is unacceptable, there is no choice but to leave the stands uncut.

To reduce the sudden and severe visual impact on the landscape, openings cut in stands for timber and water production, wildlife habitat improvement, and recreation (ski runs) should be a repetition of natural shapes, visually tied together to create a balanced, unified pattern that will complement the natural landscape (Barnes 1971). This is especially important for those openings in the middle and background that can be seen from a distance. The foreground should be maintained in high forests under some partial cutting system.

PARTIAL CUTTING HISTORY

Most cuttings in spruce-fir forests on the National Forests before 1950 in the central and southern Rocky Mountains were of a type that could be collectively called "partial cuttings." They ranged from removal of a few individual trees to removal of all of the larger, more valuable trees in the stand. Seedbed preparation was usually limited to the disturbance created by logging, and slash was untreated or lopped. Most skidding was done with horses.

In general, heavy partial cutting — usually considered necessary to make logging profitable — was not successful as a means of arresting stand deterioration or increasing net increment on residual trees. For example, residual stands of spruce-fir in Colorado suffered heavy mortality when 60 percent of the original volume was removed by individual tree selection (Alexander 1963). Net increment was only about one-third of that in uncut stands. Similar results followed heavy partial cutting elsewhere in the central Rocky Mountains (USDA Forest Service 1933), and in the Northern Rockies (Roe and DeJarnette 1965). Even when mortality was not a problem, heavy partial cutting left the older, decadent stands in a shabby condition, with little appearance of permanent forest cover.

Windfall, the principal cause of mortality, increased as the intensity of cutting increased. Low stumpage values and the generally scattered pattern of windfall usually prevented salvage of blowdown after partial cutting. Not only was the volume of windthrown trees lost, but the combination of down spruce and overstory shade provided breeding grounds for spruce beetles (Dendroctonus rufipennis Kirby).

Partial cutting was successful — in the sense that the residual stand did not suffer heavy mortality — in some spruce-fir stands where large reserve volumes were left in protected locations. In one study in northern Idaho, windfall losses were light after a partial cutting that left 6,000 board feet per acre in spruce-fir stands in a sheltered location on deep, well-drained soil (Roe and DeJarnette 1965). On the Grand Mesa National Forest in Colorado, where spruce trees are relatively short and no serious wind problems are associated with topography, few trees blew down when about 40 percent of the original volume was removed from two-storied stands. In single-storied stands, however, only about 30 percent of the original volume could be safely removed. On the other hand, heavier partial cutting that removed 50 percent or more of the original volumes per acre from spruce-fir forests in the dry "rain shadow" of the Continental Divide on the Rio Grande National Forest did not result in blowdown to the residual stand. However, these two-storied stands were growing on sites where productivity was very low. Individual trees were short, widely spaced, and therefore relatively windfirm before cutting.

There are also numerous examples of early cuttings — between 1910 and 1930 — on many National Forests in Colorado where very light partial cutting — removal of 10 to 15 percent of the stand — did not result in substantial windthrow of residual trees.

Although an overstory tends to favor fir reproduction over spruce, regeneration success of spruce has been acceptable under a wide variety of partial cutting treatments (Alexander 1963, Roe and DeJarnette 1965).

SUSCEPTIBILITY TO WIND AND INSECTS

Windfall

Windfall is a common cause of mortality after any kind of initial cutting in old-growth spruce-fir forests, but partial cutting increases the risk because the entire stand is opening up and therefore vulnerable. While the tendency of spruce to windthrow is usually attributed to a shallow root system, the development of the root system varies with soil and stand conditions. On medium to deep, well-drained soils, trees have a better root system than on shallow, poorly drained soils. Trees that have developed together in dense stands over long periods of time mutually protect each other, and do not have the roots, boles, or crowns to withstand sudden exposure to wind if opened up too drastically. If the roots and boles are defective, the risk of windthrow is increased. The presence of old windfalls in a stand is another good indicator of lack of windfirmness. Furthermore, regardless of the kind or intensity of cutting, or soil and stand conditions, windthrow is greater on some exposures than others (Alexander 1964, 1967). Exposures where windfall risk

is below average, above average, or very high have been identified as follows:

Below Average

1. Valley bottoms, except where parallel to the direction of prevailing winds, and flat areas.
2. All lower, and gentle middle north- and east-facing slopes.
3. All lower, and gentle middle, south- and west-facing slopes that are protected from the wind by considerably higher ground not far to windward.

Above Average

1. Valley bottoms parallel to the direction of prevailing winds.
2. Gentle middle south and west slopes not protected to the windward.
3. Moderate to steep middle, and all upper north- and east-facing slopes.
4. Moderate to steep middle, south- and west-facing slopes protected by considerably higher ground not far to windward.

Very High

1. Ridgetops.
2. Saddles in ridges.
3. Moderate to steep middle south- and west-facing slopes not protected to the windward.
4. All upper south- and west-facing slopes.

The risk of windfall in these situations is increased at least one category by such factors as poor drainage, shallow soils, defective roots and boles, or overly dense stands. Conversely, the risk of windfall is reduced if the stand is open-grown or composed of young, vigorous, sound trees. All situations become **very high** risk if exposed to special topographic situations such as gaps or saddles in ridges at higher elevations to the windward that can funnel winds into the area.

Insects

A large number of insect pests infest Engelmann spruce (Keen 1952). The spruce beetle is the most serious in mature to overmature stands, and epidemics have occurred throughout recorded history (Hopkins 1909, Massey and Wygant 1954). The most damaging outbreak was in Colorado from 1939-51, when beetles killed nearly 4 billion board feet of standing spruce. Most attacks have been associated with extensive windthrow, where down trees provided an ample food supply for a rapid buildup of beetle populations (Massey and Wygant 1954, Wygant 1958).

Cull material left after logging has also started outbreaks, and there are examples where heavy spruce beetle populations have developed in scattered trees windthrown after heavy partial cutting. The beetle progeny have then emerged to attack living trees, sometimes seriously damaging the residual stand. Occasionally heavy spruce beetle outbreaks have developed in overmature stands with no recent history of cutting or windfall, but losses in uncut stands that have not been subjected to catastrophic windstorms have usually been no greater than normal mortality in old growth.

Overmature trees are attacked first, but if an infestation persists, beetles will attack and kill smaller diameter trees after the larger trees in the stand are killed. In the central Rocky Mountains, susceptibility of spruce stands in relation to location, increases in the following order: (1) immature stands, (2) mixed stands, (3) poorer stands on benches and high ridges, (4) better stands on benches and high ridges, (5) trees in creek bottoms (Schmid and Beckwith 1971). For individual stands, analysis of past infestations suggests the following characteristics are potentially associated with outbreaks: (1) single- or two-storied stands, (2) high proportions of spruce in the overstory, (3) basal area of 150 square feet per acre or more in the older and larger trees, and (4) an average 10-year periodic diameter growth of 0.4 inch or less.[3]

In infested stands, or those with potential beetle problems, felling and salvaging attacked or susceptible trees, and disposing of green cull material, is the most effective silvicultural control. However, partial cutting that removes the larger overmature trees and releases the younger trees also reduces potential insect problems in stands with a good stocking of trees in the smaller diameter classes. "Trap trees" intentionally felled prior to beetle flight, are highly attractive and often provide an effective way of concentrating and trapping spruce beetles (Nagel et al. 1957). After the beetles enter the downed logs, they are usually

[3] *Schmid, J.M., and T.E. Hinds. "Spruce beetle outbreak areas." (Manuscript in preparation at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.)*

salvaged, but may be chemically treated or burned (Schmid and Beckwith 1971). Lethal traps in which cacodylic acid is used to prevent brood development appears to be a potentially useful refinement to the regular trap tree approach (Buffam et al. 1973).

STAND CONDITIONS

Old-growth spruce-fir forests grow on a wide range of sites, with a great diversity of stand conditions and characteristics. This diversity complicates the development of silvicultural systems needed to convert old-growth to managed stands for a variety of uses. For example, spruce-fir forests are the dominant elements in a number of near-climax vegetation associations throughout the central and southern Rocky Mountains, but frequently they do not have the age-class structure of true climax forests. Some stands are clearly single-storied, indicating that desirable spruce forests can be grown under even-aged management. Others are two- or three-storied, and multi-storied stands are not uncommon (LeBarron and Jameson 1953, Miller 1970). This structure may be the result of either past disturbances such as fire, insect epidemics, or cutting, or the gradual deterioration of old-growth stands associated with normal mortality from wind, insects, and diseases. Gradual deterioration is especially evident in the formation of some multi-storied stands. On the other hand, some multi-storied stands appear to have originated as uneven-aged stands and are successfully perpetuating this stand structure.

The composition of spruce and fir varies considerably with elevation. At middle elevations (10,000 to 11,000 feet) on north slopes, forests are frequently pure spruce in the overstory with fir predominating in the understory. In the central Rocky Mountains, for example, spruce commonly makes up 70 percent or more of the overstory basal area, and fir from two-thirds to three-fourths of the understory and advanced reproduction (Alexander 1957, 1963; Oosting and Reed 1952). This composition in relation to structure has developed under natural conditions because spruce is more exacting in its seedbed requirements and less able to compete with fir under low light intensities common to dense forests. Once established, however, spruce lives longer than fir and is less susceptible to disease (Alexander 1958). Exceptions are stands attacked by spruce beetles, where fir is the dominant element in both the overstory and understory.[3]

At higher elevations (above 11,000 feet elevation), spruce may form essentially pure stands, while at lower elevations where sites are usually drier, the density of spruce relative to fir may be low. In these latter situations, and at middle elevations on south and west slopes, lodgepole pine (Pinus contorta Dougl.) is frequently more numerous in the overstory than spruce. Aspen (Populus tremuloides Michx.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco) also grow with spruce at middle and low elevations.

Advanced spruce and fir reproduction is likely to be older than it appears because the early growth of both is slow. Spruce commonly takes from 20 to 40 years to reach a height of 4 to 5 feet, even under favorable conditions; under a dense canopy, spruces 4 to 6 feet tall may be 75 years or more old (Oosting and Reed 1952). Spruce and fir reproduction suppressed for long periods of time will respond to release, however, and make acceptable growth.

PARTIAL CUTTING PRACTICES

Partial cutting here includes both shelterwood and selection cuts and their modifications. They are regeneration systems that harvest the timber on an area in more than one step. From a silvicultural point of view these are acceptable harvesting methods in old-growth spruce-fir. They are, in fact, the only options open to the manager where (1) multiple-use considerations preclude clearcutting, (2) combinations of cleared openings and high forests are needed to meet various resource use requirements, or (3) areas are difficult to regenerate after clearcutting. However, windfall, insects, and stand conditions impose limitations on how stands can be handled. Cutting to bring old-growth under management is likely to be a compromise between what is desirable and what is possible. Management may involve a combination of several partial cutting treatments, continuous sanitation salvage cutting, clearcutting, and no cutting on many areas.

A **careful appraisal** of the capabilities and limitations of each stand is necessary to determine cutting practices. Furthermore, partial cutting requires **careful marking** of individual trees or groups of trees to be removed, and **close supervision** of logging. The following partial cutting recommendations are keyed to broad stand descriptions, windfall risk situations, and insect problems with the objective of maintaining permanent forest cover to meet the needs of different resource uses.

SINGLE – STORY

Single-Storied Stands[4]

Description

1. May appear to be even-aged, but usually contain more than one age class. In some instances, the canopy may not appear to be of uniform height because of changes in topography, stand density, or stocking.
2. Codominant trees form the general level of the overstory canopy. Dominants may be 5 to 10 feet taller, and occasionally predominants may reach 15 to 20 feet above the general canopy level. Taller intermediates extend into the general canopy; shorter intermediates are below the general canopy level but do not form a second story.
3. Small range in diameters and crown length of dominants and codominants.
4. Few coarse-limbed trees in the stand: if two-aged or more, younger trees usually have finer branches and may not have diameters equal to the older trees.
5. Trees more often uniformly spaced than clumpy.
6. Usually does not have a manageable stand of advanced reproduction.[5]
7. If lodgepole pine is present in the overstory it is not a major stand component. Lodgepole pine reproduction is absent or sparse.[6]

Recommended Cutting Treatments

These stands are usually the least windfirm because trees have developed together over a long period of time and mutually protect each other from the wind.

1. If the windfall risk is below average, and the trees are uniformly spaced —

a. The first cut should be light, removing about 30 percent of the basal area of the stand on an individual tree basis.[7] This type of cutting resembles the first or **preparatory cut** of a three-step shelterwood. Since all overstory trees are about equally susceptible to windthrow, the general level of the canopy should be maintained by removing some trees from each overstory crown class. Those trees with known indicators of defect should be removed first, but avoid creating openings in the canopy with a diameter larger than one tree height by distributing the cut over the entire area. Do not remove dominants in the interior of the stand that are protecting other trees to their

[4] *Reproduction less than 4.5 feet tall is not considered a stand story in these descriptions.*

[5] *Since any kind of cutting in spruce-fir forests may destroy as much as half of the advanced reproduction, even with careful logging, at least 600 seedlings and saplings per acre, of good form and vigor and free of defect, must be present to be considered a manageable stand (Roe et al. 1970). Needless destruction of a manageable stand of advanced reproduction because the composition is largely fir is not justified when one of the management objectives is to establish and maintain forest cover.*

[6] *Where mixed stands of spruce, fir, and lodgepole pine occur, pine, relative to its position in the canopy, should be handled the same as spruce.*

[7] *As a practical matter, small saplings that do not represent significant competition to the remainder of the stand may be excluded from the computation of basal area.*

leeward if these latter trees are to be reserved for the next cut. In these, and all other stands containing natural openings one to several tree heights in diameter, leave the trees around the perimeter for a distance of about one tree height until the final entry. These trees have been exposed to the wind and are usually windfirm, and protect the trees in the interior of the stand.

b. The second entry into the stand should not be made for at least 5 to 10 years after the first cut, to determine if the remaining trees are windfirm. This cut should also remove about 30 percent of the original basal area on an individual tree basis. Any windfall salvaged after the first cut should be included in the computation of basal area to be removed. This cut simulates the second or **seed cut** of a three-step shelterwood. The largest and most vigorous dominants and codominants should be reserved as a seed source, but avoid cutting openings in the canopy larger than one tree height in diameter by distributing the cut over the entire area, even if it means leaving trees with poor seed production potential.

c. The last entry is the **final harvest** and should remove all of the remaining original overstory. It should not be made until a manageable stand of reproduction has become established, but the cut should not be delayed beyond this point if timber production is one of the primary concerns because the overwood hampers the later growth of seedlings.

d. The manager also has the option of removing less than 30 percent of the basal area at any entry and making more entries, but they cannot be made more often than every 5 to 10 years. This will spread the cut out and maintain a continuous forest cover for a longer period of time.

2. If the windfall risk is below average, and the trees are clumpy —

a. The first cut should be a modified **group selection** that removes about 30 percent of the basal area. Harvesting timber in groups will take advantage of the natural arrangement of trees in clumps. Group openings should be kept small — not more than one to two tree heights in diameter — and not more than one-third of the area should be cut over. However, all trees in a clump should be either cut or left since they mutually support each other, and removing only part of a clump is likely to result in windthrow of the remaining trees.

b. The second entry into the stand should not be made until the first group of openings has been regenerated. This cut can also remove about 30 percent of the original basal area, but without cutting over more than an additional one-third of the area. Openings should be no closer than about one to two tree heights to the openings created by the previous cut.

c. The final entry should remove the remaining groups of merchantable trees. The timing of this cut depends upon how the manager elects to regenerate the openings. If he chooses to use natural regeneration, the final harvest must be delayed until the regeneration in the openings cut earlier are large enough to provide a seed source.

d. The manager may choose to remove less than 30 percent of the basal area and cut over less than one-third of the area at any one time. This will require more entries, but no new cut should be made until the openings cut the previous entry have regenerated. The last groups cannot be cut until there is a seed source unless the manager elects to plant these openings.

3. If the windfall risk is above average, and the trees are uniformly spaced —

a. The first cut should be restricted to a very light **preparatory** cutting that removes about 10 percent of the basal area on an individual tree basis. The objective is to open up the stand but at the same time minimize the windfall risk to the remaining trees. This type of cutting resembles a **sanitation cut** in that the poorest risk trees — those of low vigor and with known indicators of defect — and predominants should be removed, but it is important that the general level of the overstory canopy be maintained intact. Provision should be made to salvage windfalls after spruce beetle flight at the end of July.

b. The second entry can be made in about 10 years after the first cut. This entry should remove about 15 to 20 percent of the original basal area on an individual tree basis. Any windfall salvaged after

the first cut should be included in the computation of the basal area to be removed. The objective of this **preparatory cut** is to continue to open up the stand gradually while preparing the stand for the seed cut. Most of the trees marked for removal should come from the intermediates and small codominants, but maintain the general level of the canopy intact.

c. It will require another 5 to 10 years to determine if the stand is windfirm enough to make another entry. This will be the **seed cut** and should remove about 20 to 25 percent of the original basal area, including any windfalls salvaged after the last cutting. The largest and most vigorous dominants and codominants should be reserved as a seed source, but it is more important to distribute the cut over the entire area.

d. The last entry is the **final harvest**, which should remove the remaining original overstory. It cannot be made until a manageable stand of reproduction has been established. About 50 percent of the original basal area will be removed in this cut. If this harvest is more than 10,000 board feet per acre, it is probably too heavy to be removed in one cut without undue damage to the reproduction. The manager must then plan on a final harvest in two steps. The second step can begin as soon as the skidding is finished in the first step, providing that a manageable stand of reproduction still remains.

4. **If the windfall risk is above average and the trees are clumpy —**

   a. The first cut should be light, removing about 15 to 20 percent of the basal area in a modified **group selection**. Group openings should be no larger than one tree height in diameter, and not more than one-fifth of the area should be cut over at any one time. All trees in a clump should be cut or left. In stands with small natural openings — about one tree height in diameter — the openings can be enlarged one tree height by removing clumps of trees to the windward.

   b. Four additional entries into the stand can be made at periodic intervals, but no new entry should be made until the openings cut the previous entry have regenerated. The last groups to be removed should be retained until trees in the original openings are large enough to provide a seed source. About 20 percent of the basal area should be removed over about one-fifth of the area at each entry. Group openings should be no larger than one tree height in diameter.

5. **If the windfall hazard is very high —**

   The choice is limited to removing all the trees or leaving the area uncut. Cleared openings should not be larger than regeneration requirements dictate, and they should be interspersed with uncut areas of at least equal size. Not more than one-third of the total area in this wind risk situation should be cut at one time.

TWO-STORY

Two-Storied Stands

Description

1. May appear to be two-aged, but usually contains more than two age classes.
2. Top story (dominants, codominants, and intermediates) is usually spruce; resembles a single-storied stand.
3. Second story is often fir, and the trees are younger and smaller in diameter than the overstory. May consist of small saw logs, poles, or large saplings, but is always below the top story and clearly distinguishable from the overstory. Trees in the second story are overtopped, but not suppressed.
4. May contain a manageable stand of advanced reproduction.
5. Arrangement of individual trees varies from uniform to clumpy.
6. If lodgepole pine is present in the stand it is usually a scattered component of the overstory. Lodgepole pine reproduction is absent or sparse.

Recommended Cutting Treatments

Same as for three-storied stands.

THREE-STORY

Three-Storied Stands

Description

1. May appear to be three-aged, but usually contains more than three age classes. Occasionally two-aged, but is never all-aged.
2. If three-aged or more, top story usually predominantly spruce and resembles a single-storied stand except that there are fewer trees. Second and third stories usually consist of younger, smaller diameter trees (that is, small saw logs, poles, and large saplings), usually fir. In a typical stand, the second story will be 10 to 30 feet below the top story and consist of small saw logs or large poles. Third story will be 10 to 30 feet below the second story and consist of small poles or large saplings. Although the second and third stories are overtopped, the trees are usually not suppressed.
3. If two-aged, first two stories are old-growth with spruce in the top story and fir in the second story. The third story will be younger trees, largely fir, of smaller diameter.
4. Frequently contains a manageable stand of advanced reproduction.
5. More often clumpy than single- or two-storied stands.
6. If lodgepole pine is present in the stand, it is usually a scattered component of the top story, but may occur in the second story. Lodgepole pine reproduction is usually absent or sparse.

Recommended Cutting Treatments

Trees in the overstory of two- and three-storied stands are usually more windfirm than those in single-storied stands. The second and third stories are likely to be less windfirm than the top story.

1. **If the windfall risk is below average, and the trees are uniformly spaced—**

   a. Where there is **not** a manageable stand of advanced reproduction:
   (1) The first cut can remove about 40 percent of the basal area. This type of cutting is heavy enough to resemble the first step or **seed cut** of a two-cut shelterwood, but the marking follows the rules for individual tree selection — mature trees are removed from each story. Since the overstory is likely to be more windfirm, selected dominants and codominants of good vigor and free of defect should be left. These trees are also the most desirable seed source. Avoid cutting holes in the canopy larger than one tree height in diameter by distributing the cut over the entire area. Do not remove dominant trees in the interior of the stand that are protecting other trees to their leeward if these latter trees are to be reserved for the next cut.
   (2) The second entry should be the **final harvest** to remove the remaining original

stand and release the reproduction. It cannot be made until the new stand of reproduction is established. If the residual volume is greater than about 10,000 board feet per acre, the final harvest should be made in two steps to avoid undue damage to newly established reproduction. The second step can begin as soon as skidding is finished in the first step, providing that a manageable stand of reproduction still remains.

b. If there is a manageable stand of advanced reproduction, the first cut can be an overstory removal if the volume is not too heavy. Otherwise, the first cut can remove 40 percent of the basal area on an individual tree basis as long as the more windfirm dominants and codominants are left. The timing of the second cut is not critical from a regeneration standpoint, providing a manageable stand of reproduction still remains after the first cut and can be saved.

c. The manager has other options to choose from. He may elect to cut less than the recommended basal area, make more entries, and spread the cut out over a longer period of time by delaying the final harvest until the new stand is tall enough to create a continuous high forest. He may also elect to convert these stands to an uneven-aged structure by making a series of light cuts — 10 to 20 percent of the basal area — at frequent intervals — 10 to 20 years. Ultimately the stand will contain a series of age classes.

2. **If the windfall risk is below average, and the trees are clumpy—**

a. The first cut should remove about 40 percent of the basal area in a modified **group selection** cutting. The group openings can be larger (two to three times tree height) than for single-storied stands, but the area cut over should be not more than one-third of the total. The group openings should be irregular in shape but without dangerous, windcatching indentations in the edges. All trees in a clump should either be cut or left.

b. Two additional entries can be made in the stand. They should each remove about 30 percent of the original basal area in group openings up to two to three times tree height, but not more than one-third of the area should be cut over at any one time. If there is not a manageable stand of advanced reproduction, the manager must wait until the first group openings are regenerated before cutting the second series. Furthermore, he must either delay the cutting of the final groups until there is a seed source or plan on planting these openings. If there is a manageable stand of advanced reproduction, the timing between cuts is not critical from a regeneration standpoint.

c. The manager has the option of removing less than the recommended basal area and cutting less than the recommended area at any one time. This will require more entries and spread the cut out over a longer period of time.

3. **If the windfall risk is above average, and the trees are uniformly spaced—**

a. The first cut should be a light **preparatory** cut that removes not more than 20 percent of the basal area, on an individual tree basis, where there is not a manageable stand of advanced reproduction. Predominants, intermediates with long, dense crowns, and trees with known indicators of defect should be removed first, but maintain the general level of the canopy. The objective of this cut is to open up the stand but at the same time minimize the windfall risk to the residual stand. Provision should be made to salvage windfalls after spruce beetle flight.

b. The second entry into the stand should not be made within 10 years. This cut should remove about 30 percent of the original basal area, including the salvage of any windfalls that occur between the first and second cuts. Because the second entry is the **seed cut** the best dominants and codominants should be reserved as a seed source, but it is important that the cut be distributed over the entire area.

c. The next entry is the **harvest cut** to remove the remaining merchantable volume and release the established new reproduction. However, if volume of the residual stand is too heavy, the final harvest should be made in two steps.

d. If these stands contain a manageable stand of reproduction and the volume per acre is not too heavy, the first cut can be an **overwood removal**. If the volume is too heavy for a one-step removal, the manager should follow the recommendations 3a-c because the wind

hazard is too great to permit a two-step removal in a stand that has not been previously opened up.

4. **If the windfall risk is above average, and the trees are clumpy—**

   a. The first cut should be a **modified group selection** that removes about 25 percent of the basal area. Group openings should be kept small — not more than one to two tree heights in diameter — and not more than one-fourth of the area should be cut over at any one time. All trees in a clump should either be cut or left. Small natural openings can be enlarged one to two tree heights by removing trees in clumps to the windward of the opening.
   b. Three additional entries should be made in the stand. About 25 percent of the original basal area should be removed on about one-fourth of the area each entry. If there is not a manageable stand of advanced reproduction, the interval between cuts will depend upon the time required to regenerate each series of openings. The manager must either delay the removal of the final groups until a seed source is available or plant the openings. If there is a manageable stand of advanced reproduction, the timing between cuts is not critical from a regeneration standpoint.

5. **If the windfall hazards are very high—**

   The choice is usually limited to removing all the trees or leaving the area uncut. Cleared openings should not be larger than regeneration requirements dictate, and should be interspersed with uncut areas. Not more than one-third of the total area in this windfall risk situation should be cut over at any one time.

MULTI - STORY

Multi-Storied Stands

Description

1. Generally uneven-aged with a wide range in diameters.
2. If the stand developed from a relatively few individuals, overstory trees are coarse limbed, fill-in trees are finer limbed. Overstory trees may be relatively vigorous.
3. If the stand developed from the deterioration of a single- or two-storied stand, overstory may be no limbier than fill-in trees. Much of the vigorous growing stock is below saw log size.
4. Almost always contains a manageable stand of reproduction as a ground story.
5. Fill-in trees may be clumpy, but usually not the overstory.
6. Lodgepole pine may occur as a scattered component of the stand, usually in the overstory, but may occur in all stories including reproduction.

Recommended Cutting Treatments

These stands are usually the most windfirm, even where they have developed from the deterioration of single- and two-storied stands, because by the time they have reached their present condition, the remaining overstory trees are usually windfirm.

1. If the windfall risk is below average—

There is considerable flexibility in harvesting these stands. All size classes can be cut with emphasis on either the largest or smallest trees in the stand. For example, the first cut can range from removal of all large trees in the overstory to release the younger growing stock, to a thinning from below to improve the spacing of the larger trees. If the manager elects to make an overwood removal and the volume is too heavy, it should be harvested in two steps. Thereafter, cutting can be directed toward either even- or uneven-aged management, with entries made as often as growth and regeneration needs dictate.

2. If the windfall risk is above average or very high—

The safest first cut is an overwood removal with a thinning from below to obtain a wide-spaced, open-grown stand that will develop windfirmness. Thereafter, cutting can be directed toward either even- or uneven-aged management.

Modifications to Cutting Treatments Imposed by Spruce Beetles

1. If spruce beetles are present in the stand at an endemic level, or in adjacent stands in sufficient numbers to make successful attacks, and:

   a. Less than the recommended percentage of basal area to be removed is in susceptible trees, any attacked and all susceptible trees should be removed in the first cut. This will include most of the larger spruce trees and is therefore a calculated risk, especially in above-average wind risk situations. Furthermore, the percentage of fir in the stand will increase. Provision should be made to salvage attacked trees. The remaining cuts should be scheduled in accordance with windfall risk, insect susceptibility, and regeneration needs.

b. More than the recommended percentage of basal area to be removed is in susceptible trees, the manager has three options: (1) remove all the susceptible trees, (2) remove the recommended basal area in attacked and susceptible trees and accept the risk of future losses, or (3) leave the stand uncut. If the stand is partially cut or left uncut, probably less than half of the residual basal area would be lost, but most of the surviving merchantable spruce would be small-diameter trees.

2. If an infestation is building up and the manager chooses to either partially cut or leave the stand uncut because clearcutting is unacceptable, he must accept the risk of an outbreak that will destroy most of the merchantable spruce in the stand and spread to adjacent stands.

Cutting to Save the Residual

Before any cutting begins, the manager must determine whether he has an acceptable stand of advanced reproduction and if he is going to manage it. Furthermore, he must reevaluate the stand after the final harvest and slash disposal to determine the need for supplemental stocking. The same criteria used to evaluate advanced reproduction on clearcut areas applies here (Roe et al. 1970).

In partial cutting, protection of the residual from logging damage is of primary concern. The residual includes merchantable trees left after shelterwood cutting, and advanced reproduction in both shelterwood and group selection cutting where an acceptable stand is to be managed. Protection begins with a well-designed logging plan at the time of the first cut. To minimize damage, skid roads must be layed out — about 200 feet apart depending on the topography — and marked on the ground. These skid roads should be located so that they can be used to move logs out of the woods at each cut. Close supervision of logging will be required to restrict travel of skidding and other logging equipment to the skid roads.

In shelterwood cuttings, trees should be felled into openings as much as possible, using a herringbone pattern that will permit logs to be pulled onto the skid roads with a minimum of disturbance. It may be necessary to deviate from the herringbone felling angle to drop trees into openings. If this is the case, the logs should be bucked into short lengths to reduce skidding damage. Trees damaged in felling and skidding should not be removed if they are still windfirm. In group selection cutting, the felling pattern should be similar where there is a manageable stand of advanced reproduction. Otherwise all trees should be felled into the openings. Both shelterwood and group selection cuttings require close coordination between felling and skidding because it may be necessary to skid one tree before another tree is felled.

REGENERATION PRACTICES

Some slash disposal will probably be needed after each cut but it should be confined to concentrations and that needed to reduce visual impact; most equipment now available for slash disposal is not readily adaptable to working in shelterwood cuttings. Furthermore, burning slash will cause additional damage to the residual. Skid out as much of the down sound dead and green cull material as possible for disposal at the landings or at the mill. Some hand piling or scattering may be needed where slash disposal equipment cannot be used. In group-selection cutting, if there is not a manageable stand of advanced reproduction, dozers equipped with brush blades can be used to concentrate slash for burning in the openings cut. Piles should be kept small to reduce the amount of heat generated. Leave some of the larger pieces of slash and other debris in place to provide shade for new seedlings, but cut green spruce material over 8 inches in diameter should be removed or treated to reduce the buildup of spruce beetle populations.

On areas to be regenerated by new reproduction, a partial overstory canopy or trees standing around the margins of small openings provide two of the basic elements necessary for regeneration success — a seed source within effective seeding distance, and an environment compatible with germination, initial survival, and seedling establishment. The manager must make sure that the third element — a suitable seedbed — is provided after the seed cut where shelterwood cutting is used, and after each cut where group selection is used. Unless at least 40 percent of the available ground surface is exposed mineral soil after logging and slash disposal, additional seedbed preparation is needed. Until special equipment is developed, the same problem exists in shelterwood cuttings as with slash disposal. The equipment available today is too large to work well around standing trees. The smaller machines equipped with suitable attachments will have to be used, but they must be closely supervised to minimize damage to the residual.

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Guidelines are provided to aid the forest manager in developing partial cutting practices needed to convert old-growth spruce-fir forests into managed stands, while maintaining continuous forest cover in travel influence zones and areas of high recreational values or outstanding scenic beauty. These guidelines consider stand conditions, windfall risk, and insect susceptibility. The cutting practices can be used in combination with small cleared openings to create the kinds of stands desirable for increased water yields, to improve wildlife habitat, and to integrate timber production with other uses. They can also be used on areas that are difficult to regenerate where timber production is the primary objective.

Oxford: 221.42:421.1. **Keywords:** Partial cutting, windthrow, multiple use (forest resources), *Picea engelmannii, Abies lasiocarpa.*

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